Biological Report 82(11.89)
January 1989

TR EL-82-4

Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest)

PACIFIC RAZOR CLAM

Fish and Wildlife Service

U.S. Department of the Interior

Coastal Ecology Group
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PACIFIC RAZOR CLAM

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Waterways Experiment Station
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U.S. Department of the Interior
Fish and Wildife Service
Research and Development
National Wetlands Research Center
Washington, DC 20240

This series should be referenced as follows:

U.S. Fish and Wildlife Service. 1983-19__. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. U.S. Fish Wildl. Serv. Biol. Rep. 82(11). U.S. Army Corps of Engineers, TR EL-82-4.

This profile should be cited as follows:

Lassuy, D. R., and D. Simons. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)-- Pacific razor clam. U.S. Fish. Wildl. Serv. Biol. Rep. 82(11.89). U.S. Army Corps of Engineers, TR-EL-82-4. 16pp.

PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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or

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Attention: WESER-C
Post Office Box 631
Vicksburg, MS 39180

CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km*)	0.3861	square miles
hectares (ha)	2.471	acres
liters (1)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees ("C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft.)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

CONTENTS

ACKNOWLEDGMENTS

We wish to thank Darrell Demory (Oregon Department of Fish and Wildlife, Newport) who provided much of the significant literature on razor clams as well as extensive information on razor clam populations in Oregon. Jerry Lukas (ODFW, Portland) provided economic and catch data for the Oregon razor clam fishery. We also thank Kenneth Chew (University of Washington, School of Fisheries) for his assistance and constant encouragement, and Terrance Link (Oregon Department of Fish and Wildlife, Astoria) who reviewed the manuscript. Thanks also go to Doris Small, Alan Rammer, and Thorn Hooper for their assistance in researching Washington data to Adrian Hunter who prepared the manuscript.

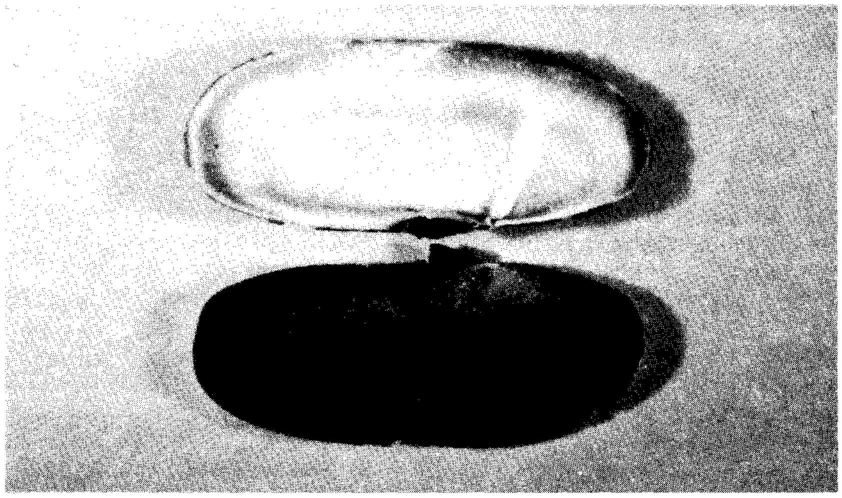

Figure 1. Pacific razor clam (from Fitch 1953).

PACIFIC RAZOR CLAM

NOMENCLATURE/TAXONOMY/RANGE

Scientific name .... *Siliqua patula* (Dixon)
Common name .... Pacific razor clam (Figure 1)
Other names .... Northern razor clam
Class .... Pelecypoda
Order .... Veneroida
Family .... Solenidae

Geographic range: Razor clams are found on open sandy beaches from Pismo Beach in southern California to the Aleutian Islands in Alaska. The distribution in the Pacific Northwest Region is shown in Figure 2.

MORPHOLOGY/IDENTIFICATION AIDS

Fitch (1953) described the razor clam as follows: "Elongate shells, thin, flat and smooth; covered with a heavy, glossy, yellowish periostracum, a prominent rib extending from the umbo to the margin on the inside of the valve. Foot large and powerful, never pigmented. Siphons rather short and united except at tips. Umbos nearer anterior than posterior end. Attains a length of seven inches. Differs from the rosy (*Solen rosaceus*) and sickle (*S. sicarius*) razor clams and the jack-knife (*Tagelus californianus*) clam by having a heavy, raised rib extending from the umbo to the margin of the shell on the inside."

Weymouth and McMillin (1931) further distinguished the relatively nonpigmented *S. patula* from a similar razor clam, *S. alta*, by the presence of "chocolate-brown" coloration on the foot, mantle, and siphon of *S. alta*. Differences in umbo position, growth pattern, variability, and rib direction were also detailed. These same characteristics are also used to distinguish *S. patula* from *S. sloati*

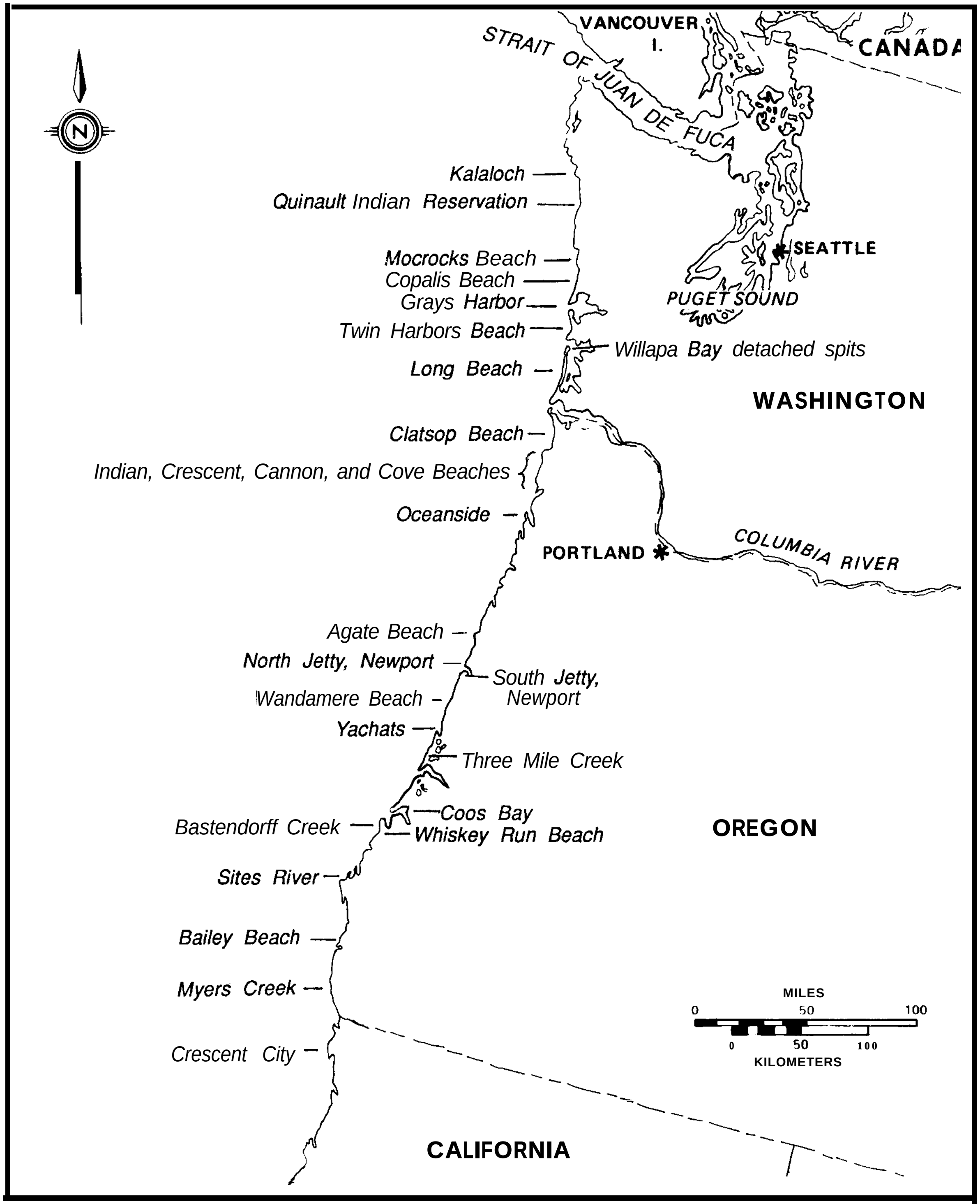

Figure 2. Distribution of the Pacific razor clam in the Pacific Northwest Region. Long Beach, Twin Harbors, Copalis Beach, and Mocrocks Beach in Washington and Clatsop Beach in Oregon are the primary razor clam beaches. All others are only intermittently populated to much extent.

which is found in subtidal areas only (Hertlein 1961). Quayle (1962) described razor clam shells as thin and brittle; olive green in youth, changing to brown with age. Weymouth et al. (1925) noted that razor clams that had never spawned had a "translucent appearance." Once spawning had occurred, the shells became very dark and did not regain translucence.

REASON FOR INCLUSION IN SERIES

The razor clam is often referred to as the finest food clam available on Pacific beaches. It is "the basis of economically important commercial and recreational fisheries throughout much of its range' (Breese and Robinson 1981). Commercial fishing for razor clams has existed since before the turn of the century but is now being largely replaced by recreational digging. Millions of clams are taken annually from Washington and Oregon beaches. This increasing popularity led Browning (1980) to write that "many Washington residents, as well as a great number of Oregonians, consider razor clam digging Number One among outdoor activities."

LIFE HISTORY

Spawning and Larvae

In the Pacific Northwest, razor clams generally spawn in late spring or early summer. Spawning seasons are progressively later at more northern locations. On the Alaskan Peninsula, for example, spawning may peak as late as August (Weymouth et al. 1925). Peak spawning time for razor clams on Washington beaches varies from mid-May through July. While the spawning season is usually more protracted, McMillin (1924) estimated that 98% of the razor-clam spawn at Copalis Beach, Washington in 1923 occurred over only a 2- to 4-day period in late May. He further suggested that the degree of simultaneity may be density-dependent. Variations in local spawning times may also depend on food availability (Breese and Robinson 1981) or other environmental conditions (see section on Temperature). In some populations, a second, much smaller spawning peak may occur in late summer or early fall (McMillin 1924). Some spawning may take place throughout the year.

Weymouth and McMillin (1931) suggested that "neither artificial propagation nor culture are feasible." However, the State of Washington has been operating a razor clam hatchery since 1980. Breese and Robinson (1981) successfully induced spawning of *S. patula* in the laboratory by raising the concentration of their food source., the dinoflagellate *Pseudoisochrysis paradoxa*, to 2-2.5 million cells per milliliter. There is interest in artificial propagation, particularly in Washington, because of recent losses of natural populations to disease.

Individual razor clams are either male or female rather than hermaphroditic with the sex ratio of the adult clams being 1 to 1 (Nickerson 1975). Eggs and sperm are broadcast into the water column where fertilization occurs. Ovary and testes are normally rather hard for the casual observer to differentiate. However, in advanced stages of development just prior to spawning, eggs are granular and sperm are very milky (Weymouth et al. 1925). McMillin (1924) published illustrations and photographs of several developmental stages. He described free-floating eggs as "pear shaped, with a white spot in the center." In his observations of eggs and larvae, he noted that cleavage was complete and unequal and that zygotes soon became rounded rather than pear-shaped. Veligers were formed within 10 days at 11-15 °C; by 3 weeks, they had taken on a "common clam shape" (i.e., round in valve view, heart-shaped in cross section). At 5 weeks, a distinct foot had formed but the entire animal was still transparent. At 8 weeks, the velum was gone, the shell had become opaque, and the clams had begun to elongate. Setting occurred at about 10 weeks. Breese and Robinson (1981) noted in laboratory studies (at 16.5 "C) that egg diameter averaged slightly over 90 mm. Within 48 h, larvae were straight-hinged and had reached 110 mm. Metamorphosis, apparently comparable to McMillin's "common clam shape" stage, occurred 20 to 25 days after fertilization.

Weymouth et al. (1925) reported that "eggs sink quite rapidly and are not easily raised by surf action." However, McMillin (1924) suggested that larvae were easily moved and subject to redistribution of "at least several miles." Both McMillan (1924) and Weymouth et al. (1925) suggested that larval dispersal was limited because of the brevity of the swimming larval stage and the tendency of larvae to remain in the sand.

Juveniles and Adults

After a 5- to 16-week larval life span, juvenile clams begin to set (=settle out) and dig into the sand. Weymouth et al. (1925) reported that the density of razor clams 1 to 3 months after setting "is sometimes enormous on the Washington coast" with densities approaching 1500/ft ^{2} (16,150/m ^{2}). Tegelberg and Magoon (1969) reported average setting densities of 1,385/ft ^{2} (14,900/m ^{2}) on Copalis Beach and 3,685/ft ^{2} (39,665/m ^{2}) on Mocrocks Beach, both in Washington, during the summer of 1966. Windrows of young clams covered the beaches in patches "several inches deep and several acres in extent." Densities from zero to 100/ft ^{2} (1,076/m ^{2}) are more common. Bourne and Quayle (1970) recorded highest setting densities in the lower one-third of the intertidal zone in fine, firm, damp sand. In this same study, Bourne and Quayle observed that young clams moved laterally along the surface of the sand as far as 30 cm. Thus, there may be a limited amount of directed redistribution of juveniles after setting. Rickard et al. (1986) hypothesized a complex mechanism involving growth and the movement of subtidal set clams onto intertidal beaches. Once established, juveniles over 1 inch usually remain in place in the upper few inches of sand.

Adult razor clams are usually about 1 foot beneath the surface of the sand (McMillin 1924) and show virtually no lateral movement (Bourne 1969). Although lateral movement is limited, rapid vertical mobility is characteristic of the razor clam -- as any first-time clam digger will agree. Vertical movement rates of 9 inches to 1 foot per minute have been measured (McMillin 1924; Schink et al. 1983), but many clam diggers would swear that it was more. McMillin (1924) reported one observation of a razor clam digging to a depth of 4 ft, 9 inches. This unusual ability to move so rapidly through the sand may be a consequence both of the liquidity of subsurface sand (see section on Substrate) and the digging mechanism of the razor clam. Unlike the more common flattened foot of many clams, the burrowing foot of the razor clam burrowing foot is "elongate and nearly cylindrical" (Weymouth et al. 1925). The foot is extended down into the sand, hydraulically expanded to serve as an anchor, and the muscles then contracted to pull the clam downward (Weymouth et al. 1925). McMillin (1924) associated the evolution of such mobility with the instability and transport of beach sand.

Large razor clams are densest in the lower intertidal zone (McMillin 1924; Bourne 1969; Nickerson 1975), though subtidal populations may also be substantial. For example, thousands of pounds of razor clams have been harvested at 20-40 ft in Alaskan waters. The status of subtidal populations in the Pacific Northwest is less well known. Preliminary work by the Washington Department of Fisheries (WDF) in 1983-85 indicated the presence of very few subtidal adults. However, Darrell Demory (Oregon Department of Fish and Wildlife Newport, pers. comm.) reported'diver observations along the Oregon coast of a band of adult razor clams to 8 ft, a few on the steeper drop-off to deeper water, and then common but less densely packed clams to depths of at least 20 ft. Schink et al. (1983) even suggested that "offshore clam populations are considered broodstock for intertidal populations."

The presence of substantial numbers of subtidal juveniles is more firmly established. McMillan (1924) reported having collected many small clams out to 550 yards offshore at depths of about 11 ft (3.3 m). More recently, Rickard et al. (1986) estimated subtidal densities of 38,000 clams/m^2 for juveniles from 1 to 15 mm in length.

Maturation in razor clams is apparently more closely linked with size (length) than with age. While maturity is commonly reached at a size of about 10 cm (Weymouth et al. 1925), the age at maturity varies with geographic location. Since growth is more rapid on southern beaches in the range of the razor clam (see section on Growth), maturity is reached at a lower age. Age at maturity is generally 2 years in the Pacific Northwest and 3-4 years in Alaska (Weymouth 1925). Maximum age increases sharply from 5 years in Pismo Beach, California (Weymouth et al. 1931) to 9-11 years in the Pacific Northwest (McMillin 1924; Weymouth et al. 1931) and 18-19 years in Alaska (Weymouth et al. 1931; Nickerson 1975). More recently, extensive harvest and higher natural mortality have limited longevity in the Pacific Northwest to about 7 years. A less pronounced trend in maximum size from 12 cm in Pismo Beach to 16 cm in Alaska was suggested by the early work of (Weymouth et al. 1931).

The seasonal maturation of razor clams has also been studied. Gonadal development is slowest during winter, increases as water temperature rises in spring, and peaks just before the spawning season in late spring or early summer (Weymouth et al. 1925; Bourne and Quayle 1970). Some gonadal regeneration may occur through the fall (McMillin 1924; Bourne and Quayle 1970). Bourne and Quayle also reported that females matured earlier in the season than males. At their peak, gonads may constitute 30% of the weight of the animal, exclusive of shell (McMillin 1924; Weymouth et al. 1925). Estimates of fecundity for razor clams from the Pacific Northwest beaches seem generally to refer back to McMillin's (1924) estimate of 6-10 million eggs. Nickerson (1975), however, estimated that fecundity in razor clams from Alaskan beaches ranged from 300,000 for a 40 mm clam to more than 118 million for a female of 180 mm in length.

AGE AND GROWTH

A compilation of the results of a number of growth studies across the geographic range of the razor clam is shown in Table 1. Since no consistent difference has been noted between male and female growth rates, data for both sexes are combined. In general, growth rates are higher (especially in early years), and maximum length and lifespan are shorter, in southern than in northern populations. These characteristics of growth and the more reliably high setting densities led Weymouth and McMillin (1931) and Tegelberg (1964) to suggest that Washington populations of razor clams are particularly well suited to withstand heavy exploitation. Continued heavy exploitation and recent heavy losses to disease, however, have led WDF to reduce limits and seasons. Some beaches of major importance now

Table 1. Mean length (cm) of the Pacific razor clams of different ages in different localities.

Aqe[a]	Pismo, CA[b]	Crescent Citv. CA[b]	Clahop, OR[c]	Long Beach, WA[d]	Copalis, WA[b,d,e]	Masset, BC[b]	Cordova, AK[f,g]	Swikshak, AK[b,g]	Hallo Bay AK[b]
1	1.73	1.19	2.87	3.4	2.04[a] 2.36[b] 2.9[d]	0.70	0.43[c] 0.69'	0.38[a] 0.64'	0.34
2	9.07	6.75	9.46	9.7	8.61[a] 10.5 9.49[b] [illegible]	5.35	2.38' 2.58[f]	2.73[a] 2.73'	2.25
3	11.63	10.35	11.59	11.7	10.87[a] 11.38[b] 12.9[d]	9.35	4.68' 4.82'	6.41[a] 5.91'	5.42
4	12.10	11.81	12.80	12.5	12.04[a] [illegible][b] 12.4 13.4[a]	10.97	7.73[c] 7.28[f]	9.28[a] 9.53'	8.60
5	12.68	12.58	13.52	13.2	12.81[a] 12.95[b] 14.0[d]	11.78	9.84' 9.73'	11.49[a] 11.69'	10.96
6		13.03	14.02		13.40[a] 13.58[b]	12.58	11.40[c] 11.13[f]	12.74[a] 12.91[f]	12.37
7		13.32			13.84[a] 14.03[b]	13.27	12.03' 12.51'	13.70[a] 13.90'	13.17
8		13.84			14.19[a]	13.58	12.57' 13.50'	14.19[a] 14.67[f]	13.65
9		13.51			14.50[a]	13.69	13.08' 14.09'	14.63[a] 15.15'	14.06
10						14.61	13.60' 14.48'	14.94[a]	14.44
							14.15[c] 14.85[f]	15.25[a]	14.75
12							14.90'	15.61[a]	15.08
13							15.01'	16.12[a]	15.38
14								15.96[a]	15.50
15								16.72[a]	15.80
16									15.61
17									15.74
18									16.31
19									16.74

'Listed ages represent the number of annuli present on shells. Actual ages vary from 4 to 8 months less than listed ages depending on the time of spawning and the time of annulus formation.
Sources: [b]=Weymouth, McMillin, and Rich (1931);' = Hirschhorn (1962), Table 3 totals column; [d] = Tegelberg (1964), estimated from Figure 8; [e] = McMillin (1924); [f] = Weymouth, McMillin, and Holmes (1925); [g] = Nickerson (1975), Tables 17 (Cordova) and 19 (Swikshak).

seldomly provide the recreational digger a legal limit.

Critical to the interpretation of growth studies is the precision of the aging technique. In most of the studies reported in Table 1, ages were determined by counting the number of growth rings on the shell of the clam. McMillin (1924) described a tuck that is formed between successive layers of shell that leaves "a definite mark." He concluded that these marks were annual rings (annuli). Weymouth and McMillin (1931) and Hirschhorn (1962) also concluded that such rings were valid indications of an annual pattern in shell growth. Each of these authors noted the presence of other checks or false annuli formed during spawning, storm disturbances, or other events that cause a reduction in normal growth rate. Each of these authors, however, also felt that these checks were distinguishable from annuli and that the basic aging technique was valid. Weymouth and McMillin (1931), in fact, generalized its validity to include all lamellibranchs. However, Tegelberg (1964), who, like McMillan (1924) worked at Copalis Beach, suggested that "distinct annuli appear to depend upon a pronounced winter growth slowdown, and this frequently is lacking." At least for the population he was studying, Tegelberg concluded that "aging by the ring method is of questionable validity." He preferred the use of length-frequency techniques.

As Weymouth et al. (1925) pointed out, the growing season in Alaska "is roughly one - half as long as in Washington." Due to these shorter, more defined seasons, annuli are more pronounced, more numerous, and more closely placed in Alaskan than in Washington populations of the razor clam (McMillin 1924; Weymouth et al. 1925). Regardless of geographic location, growth rate is usually slowest during late fall and winter (Weymouth et al. 1925; Hirschhorn 1962; Tegelberg 1964). Growth rate then accelerates as the water warms in spring. Another factor that consistently affects growth rate is location within the intertidal zone. Tegelberg (1964), Bourne and Quayle (1970), and Quayle and Bourne (1972) all noted higher growth rates near the low-tide line than in areas higher in the intertidal zone. Bourne (1969), commenting on this same pattern, suggested that the difference was due to the longer time spent under water, and therefore increased feeding time and growth by the clams lower in the intertidal zone. We have seen no data on the growth rates of subtidal razor clams. A very dense set may stunt the growth of some year-classes (Weymouth et al. 1925; Hirschhorn 1962; Tegelberg and Magoon 1969).

THE FISHERY

History and Regulations

Razor clams have apparently been used for personal consumption for a very long time, as they are known from Indian middens (refuse heaps) along the Pacific coast (McConnell 1972). The razor clam industry along the Pacific Coast "was pioneered by P.F. Halfarty at Skipanon, Oregon, in 1894" (Nickerson 1975). The market for fresh clams was limited at that time, but canning operations soon spread coastwide, from Oregon to the Shelikoff Straits in Alaska (Weymouth et al. 1925). By 1915, 8 million pounds of razor clams (3.2 million lb canned) were harvested and processed annually in Washington alone (Schink et al. 1983). Although some major clamming grounds (e.g., Willapa Bay and Grays Harbor) were still "totally unused" (McMillin 1924), regulatory changes were already afoot. Due to declining numbers of older clams, states began to impose restrictions on commercial harvest (Weymouth and McMillin 1931; Schink et al. 1983). Initial restrictions took the form of closures during the spawning season and size limitations.

A developing recreational use of razor clams remained largely unrestricted until the late 1920's, when bag and size limits began to be imposed. It was eventually recognized that minimum size requirements were of little use since improperly replanted razor clams were not likely to survive (D. Demory, pers. comm.). Consequently, bag limits now are accompanied by the stipulation that all razor clams, regardless of size or condition, must be kept and counted toward the daily bag. It is hoped that this stipulation will go a long way toward eliminating the waste that has plagued the fishery throughout its existence. McMillin (1924) estimated that the amount of razor clams wasted (dug and discarded due to size or injury) was nearly equal to the amount used. Wastage in 1949 was estimated at

15%-28% (Tegelberg et al. 1971). This percentage has declined over the past 10 years (Table 2), but wastage is still a significant source of mortality resulting in numerous emergency closures in Washington.

As late as 1940, the commercial catch in Oregon still composed 80% of the razor clams taken (Link 1980). After World War II, however, the numbers of tourists and resident recreational diggers of razor clams

Table 2. Numbers, pounds, and value to fishermen (all in thousands) of razor clams harvested by recreational (includes wastage) and commercial diggers from 1977-1986. All weights are whole (unshucked) weights.

	Washington[a]				Oregon[b]				
	Recreational		Commercial[c]		Recreational		Commercial		
							Landinas		
Year	Catch (No.)	Waste (%)[d]	Landings (Pounds)	Value ($)	Catch (No.)	Waste (%)	(No.)	(Pounds)	Value ($)
1977	12,600	5.8	340	302	532	6.2	143	45.8	--
1978	8,787	8.3	355	316	986	13.9	205	41.5	39.4
1979	13,025	3.9	13[e]	15	1,021	6.2	180	36.2	42.0
1980	8,304	4.6	19	20	890	16.1	116	20.3	26.6
1981	4,549	6.5	3	4	236	20.7	128	22.5	35.0
1982	7,823	5.8	8	11	881	14.0	165	26.5	42.8
1983	6,026	8.3	8	11	117’	10.3	1	0.1	0.1
1984	0[g]	--	0	0	356	4.2	37	5.8	10.4
1985	0	--	0	0	1,131	13.0	303	58.2	115.0
1986	3,169[h]	--	71	89	--	--	--	3.2	6.6
Average	6,428	6.2	82	77	683	11.6	142	26.0	35.3

[a]1 977-l 984 recreational catch numbers from Washington State Sport Catch Report series; commercial catch data from Washington Fisheries Statistical Report series; 1985 and 1986 data provided by Doug Simons.

[b]Recreational take numbers from Link (1986); 1977-1985 commercial catch data from Oregon Department of Fish and Wildlife's "Pounds and Values" series; 1986 commercial data from Jerry Lukas (ODFW, pers. comm.).

‘Number of commercially taken clams not reported for Washington. Numbers per pound may vary from 4 to 9 and are therefore not easily convertible.

[d]Percent wastage for Washington computed as weighted mean of wastage values reported for Long Beach, Twin Harbor, Copalis, and Mocrocks in WDF Sport Catch Report.

[e]Commercial razor clam fishery data limited to Willapa spits after 1978; i.e., does not include fishery on Quinault Indian Reservation.

‘El Nino year.

[g]Total closures in 1984 and 1985 due to parasitic infection of clams.

[h]Shortened season.

increased sharply. Competition from Atlantic Coast canning companies further led to the demise of many West Coast clam fisheries (Nickerson 1975). The last major public beach in Washington was closed to commercial harvest in 1968. Only the Willapa Bay spits and the Quinault Indian Reservation now maintain commercial fisheries. Recreational take now far exceeds commercial take (Table 2). The Quinault Tribal Council closed its beaches to non-Indian fishermen in 1969. Schink et al. (1983) provided a concise review of the Pacific razor clam fishery, its regulation, and jurisdictional conflicts.

Products and Clamming Sites

The primary tool of both commercial and recreational diggers is a narrow-bladed shovel called a clam gun. Tubular suction devices similar to those used for ghost shrimp are also used. Clams are dug individually. The appropriate place to dig is marked by a shallow depression ("show") left in the sand when the clam retracts its siphon. Since concentrations of large clams are densest in the lower intertidal, minus tides are particularly good times for digging.

Commercial clamming seasons coincide with the period of peak product quality and yield (Nickerson 1975) immediately before the spawning season. Canned, minced clams were formerly the major product. Most commercially harvested razor clams now go to the fresh clam market or are used as crab bait.

The digging and processing of razor clams is labor-intensive, and demand for these clams consistently exceeds supply. These conditions create relatively high and stable prices. Schink et al. (1983) reported that razor clams sold for up to 95¢/lb unshucked, $2.20 shucked, and retailed for as much as $6.50/lb at the primary markets in Portland and Seattle. As much as $2.20/lb for unshucked clams was paid to commercial diggers in Oregon in 1987. Though a stable high price and excess market demand lend themselves to "aquacultural considerations' (Schink et al. 1983), no private aquaculture operations yet produce razor clams. Since 1980, the State of Washington has produced millions of hatchery-reared razor clams for use in its experimental seeding program. Another enhancement project involved the transplantation of over 90 million small (1-15 mm) razor clams from subtidal areas to the intertidal zone (Rickard and Newman 1986).

Razor clams are dug recreationally throughout the Pacific Northwest. However, their availability is much lower in California and the southern and central coast of Oregon than to the north. Over 90% of Oregon's razor clams are dug along the 18-mi stretch of Clatsop Beach on the northern Oregon coast (Link 1980). The primary razor clam beaches of Washington are Long Beach, Twin Harbors, Copalis, and Mocrocks; Kalaloch Beach is used to lesser extent (Schink et al. 1983). Although the State of Washington requires a license for both commercial and recreational harvest of razor clams, Oregon does not currently require recreational diggers to be licensed. However, the influx of nonresidents to Oregon beaches during 1984 and 1985, when disease problems (discussed later) forced the closure of Washington beaches to razor clam digging, created pressure for the assessment of license fees.

Population Dynamics

Breese and Robinson (1981) observed that, under laboratory conditions, most larval deaths occurred at the time of metamorphosis. We have seen no comparable study under natural conditions. The determinants of the wide variability in razor clam recruitment, therefore, remain uncertain. It is noteworthy, however, that heavy sets may not be entirely beneficial to the species. Tegelberg and Magoon (1969) noted that high oceanic survival and massive setting may lead to reduced growth and increased mortality in the current-year class and to reduced growth rate in already-established adults. During one such massive set, the Washington Department of Fisheries transplanted over 300 million razor clams to less successfully recruited beaches. Though survival was not high, it was concluded that the transfer of set clams made a worthwhile addition to areas with a poor natural set (Tegelberg and Magoon 1969).

McMillin (1924) estimated a 99% mortality rate for razor clams over the first 8 months of life. Others have estimated post-setting survival rates, but are inconsistent as to the pattern of survival at progressively greater ages. Nickerson (1975) estimated annual survivals of 9% from 1 to 2 years, 30% from 2 to 3 years, and 40% thereafter. The pattern of survival in a study by Link (1980) was inverted; survival was highest (15.5%) at age 0 and lowest (0.1%) for those over 3 years of age. Link suggested, however, that his results may have been biased by disproportionately low return of tags from large clams. Hirschhorn (1962) and Link (1980) arrived at similar estimates of total instantaneous mortality rate (Z) of 2.52 and 2.34, respectively, which correspond to annual mortalities (A) of 92% and 90%. Hirschhorn (1962) further separated Z into its fishing ($F = 1.78$) and natural ($M = 0.74$) mortality components. This breakdown is similar to that of Nickerson (1975) who attributed one-third to one-half of the annual mortality rate to natural causes. Hirschhorn's estimate of natural mortality included wastage.

ECOLOGICAL ROLE

Food

Typical of bivalve molluscs, the razor clam filters its food from the surrounding water. Tegelberg and Magoon (1969) identified *Chaetoceros armatum* as "the principal food organism available to the razor clam during the period October to April" (1966-67) along the Washington coast. Lewin et al. (1979a) estimated that *C. armatum* composed 80%-100% of the diet of the razor clam. Unfortunately, no mention was made of the specifics of their estimation procedures, i.e., sampling times and frequency, sample size, and technique for gut content analysis. Several other diatoms, particularly *Asterionella socialis*, are also abundant in the surf zone along the Oregon and Washington coasts (Jijina and Lewin 1983) but are of lesser importance as a food source for razor clams. Lewin et al. (1979a) also cited the coincidence of high surf diatom standing crops with productive razor clam beaches. Breese and Robinson (1981) fed the dinoflagellate *Pseudoisochrysis paradoxa* to razor clams in laboratory aquaria.

Lewin et al. (1979b) concluded that ammonium excretion by dense populations of razor clams could play a significant role in overall nitrogen cycles of the surf environment. In particular, ammonium may serve as a nitrogen source for the maintenance of algal populations.

Sources of Mortality

The time during and immediately after setting is a particularly susceptible stage. Dense sets of razor clams may attract large numbers of avian predators. McMillin (1924) estimated that more than 20,000 seagulls were preying on newly recruited razor clams along Copalis Beach, Washington. He commented that the gulls pick up "every clam that shows on the surface of the sand and in the edge of the breakers." Interestingly, the gulls had also "learned to push their feet into the sand... shake the sand,.. causing the young clams to rise to the surface." This same observation has been made by one of the authors (DS) of the Northwestern crow, *Corvus caurinus*. They are also capable of digging up small clams by scratching the sand's surface. Other predators mentioned by McMillin were ducks and surfperches.

Similarly, Tegelberg and Magoon (1969) observed that "throughout the period of dense sets, shorebirds of the sandpiper group (Scolopacidae) were observed in great numbers feeding on razor clams." There was also predation on the clams by large numbers of glaucous-winged gulls (*Larus glaucescens*) and sea ducks, primarily surf scoters (*Melanitta perspicillata*), and white-winged scoters (*M. fusca*). Small Dungeness crabs (*Cancer magister*) were also "unusually abundant in shallow inshore lagoons where they fed on set clams." Personal observations of stomach contents of green and white sturgeon by one of the authors (DS) showed that hundreds of 1-10 mm razor clams had been ingested. Hogue and Carey (1982) reported that "young-of-the-year" razor clams were among the bivalves eaten by newly recruited English sole (*Parophrys vetulus*). We have seen no report of predation by any animal on larval or adult razor clams.

A major source of mortality, especially for young razor clams, is the scouring effect of winter storms (McMillin 1924; Tegelberg and Magoon 1969; Bourne and Quayle 1970). Bourne and Quayle suggested, in fact, that protection from winter storms was largely responsible for relatively high population numbers at Masset Beach, British Columbia. Another source of mortality in the past was automobile traffic (McMillin 1924). Auto races held on the hard-packed beaches were eventually suspended during August to avoid crushing newly set razor clams. Other known sources of mortality are discussed later.

ENVIRONMENTAL REQUIREMENTS

Temperature

Sayce and Tufts (1971) determined from laboratory experiments that the temperatures at which razor clam mortalities occurred varied with both absolute temperature and period of exposure. Mortalities began after 4 hours at 21 °C, after 3 hours at 27 "C, after 2 hours at 28 "C, and after 1 hour at 29 "C. They concluded that the "LD_{50} appears to range from about 22.5 °C for razor clams exposed 4 hours to about 27.5 °C for razor clams exposed 1 hour to warmed seawater." Bourne and Quayle (1970) attributed decreased density of razor clams from July to September partly to lethal temperatures on the British Columbia beaches that they investigated. Air temperatures near their study sites reached 23-29 °C during low tides.

Temperature and the pattern of temperature change have been used to explain spawn timing. All investigators who reported on the relation of temperature to spawning behavior agreed that an abrupt rise in ambient temperature was the trigger to the initiation of spawning. Only the actual temperature and requirements for prespawning temperature history varied among reports. Weymouth et al. (1925) noted that spawning by razor clams on Washington beaches took place on a sharp rise in water temperature at the "critical temperature" of 13 °C. They suggested that this temperature was also consistent with temperatures in Alaskan waters at the time of spawning. However, Bourne and Quayle (1970) and Nickerson (1975) have suggested that a lower triggering temperature may be more realistic for locations north of Washington.

Bourne and Quayle (1970) noted that 13 °C was not often reached in waters along British Columbia beaches and suggested that spawning might be linked to some factor(s) associated with upwelling, tidal cycle, and food availability. The experiments of Breese and Robinson (1981) lend credence to food availability as a contributing factor. Nickerson (1975) suggested a more complex set of conditions as the cue to razor clam spawning. He believed that some type of cumulative temperature factor (degree-days) was a necessary precursor to the actual triggering effect of a temperature rise. He reported that spawning began in Alaska after an abrupt rise from a mean temperature of 45 °F (7.2 "C) to 47 °F (8.3 "C).

Salinity

We found no data, experimental or field-gathered, on the effects of salinity on razor clams. McMillin (1924), however, suggested that clams that lived relatively high on the beach may be killed by heavy rains that reduce salinity. Tegelberg (1964) suggested that the influence of the Columbia River in lowering salinities at Long Beach, Washington, might account for the slower growth rate there than in the more northern, higher-salinity areas near Copalis Beach, Washington.

Oxygen

No data on the oxygen requirements of razor clams were found. McMillin (1924) mentioned oxygen as a factor in razor clam biology. He suggested "the one factor that would appear to have the greatest effect on the vertical distribution of razor clams is the oxygen content of the water." No estimate of actual requirements was made, but he wrote that razor clams will not live where aeration of the water is limited.

Substrate

Descriptions of razor clam habitat consistently include such descriptors for beaches as stable, open ocean, fully exposed, surf pounded, broad, flat, uniform, hard, and sandy (McMillin 1924; Fitch 1953; Quayle 1962; Browning 1980). Several of these terms have been discussed in detail by various authors. McMillin (1924) suggested that the fine-grain sand and gentle slopes of razor clam beaches aided in holding water in the sand between tides. These traits, he concluded, gave the beach its typically hard surface and "quicksand" subsurface texture. McMillin also noted that these beaches contained little organic matter.

Browning (1980) wrote that the pounding surf was important to the maintenance of beaches "where currents induce quick and continual change of water over the beds." This is consistent with the earlier mention by McMillin of the probable high oxygen demands of razor clams. The lack of a renewal of oxygen or possibly siltation problems may also help explain the conclusion of McMillin (1924) that razor clams "will not grow in sheltered bays."

Hirschhorn (1962) described Clatsop Beach, Oregon, more specifically as having a "flat beach-face slope (1:70) and small sand (0.2 mm)." He noted that other productive beaches had even lower slopes and finer sand. Nickerson (1975), in a survey of Alaskan razor clam beaches, observed that grain size on productive beaches was very uniform and averaged 0.16 to 0.19 mm in diameter. However, he believed that a more critical characteristic of productive beaches was a low clay fraction. Densities of razor clams were highest on beaches with the lowest percentages (0.0005% to 0.85%) of particles less than 0.005 mm in diameter. Nickerson also felt that silt-laden sediments "may cause suffocation in early life stages of razor clams." He estimated that the "critical region for lethal levels of fine substrate particles less than 0.005 mm in diameter may be approximately 2.2% of the total substrate composition.'

Nickerson (1975) also estimated upper habitable tide level (feet above mean lower low water). For beaches within the Pacific Northwest region, his estimates were as follows: Point Chehalis and Long Beach, WA, 3.4 and 3.1; Warrenton and Port Orford, OR, 3.1 and 2.7; and Crescent City, CA, 2.6.

DISEASE AND PARASITES

The occurrence of a previously unknown disease caused the complete closure of the razor clam fishery in the State of Washington in 1984 and 1985. The cause of the disease was identified as "nuclear inclusion X" (NIX), a prokaryotic pathogen, which causes an "inflammatory overgrowth of epithelial cells, congestion of respiratory spaces in the gills, rupture of gill epithelial cells, obstruction of gill epithelial cells, and the initiation of secondary infections" (Elston et al. 1986). Mortality appears to depend on prevalence and intensity of infection. NIX was "virtually 100%" present in the vicinity of Copalis and Mocrocks beaches from June 1983 to June 1985 (Elston et al. 1986). Between June 1983 and January 1984, the pathogen "presumptively caused a 95% loss" of razor clams from beaches along the central coast of Washington (Elston et al. 1986). Prevalence and intensity decreased both north and south of the central Washington beaches. The pathogen was neither found at, nor north of, the Queen Charlotte Islands in British Columbia. In Oregon, the prevalence was high--92% at Agate Beach and 100% at Clatsop Beach (Link 1986)--but intensities were low enough that mortalities were not a significant problem.

The nemertean worm *Malacobdella grossa* lives commensally in the razor clam (Oregon Fish Commission 1963). These 1- to 2-inch worms attach on the inside of the siphon but are of no harm to the clam or to the human consumer. A commensal pea crab, *Pinnixa* sp., is also routinely found in clam samples in Washington.

Paralytic shellfish poisoning is of widespread concern to consumers of bivalves. Browning (1980) reported that there had been no validated record of this problem in the history of razor clam fisheries. However, testing by the Washington State Department of Social and Health Services in 1984 revealed high levels of paralytic shellfish poison in razor clams. If the clam season had been open, Washington would have had to impose an emergency closure (Frank cox, Washington Department of Social and Health Services, Olympia; pers. comm.). Similar findings have been made from several Alaskan razor clam populations between 1985 and 1987 (Richard Barrett, Alaska Department of Environmental Conservation, Division of Environmental Health, Juneau; pers. comm.).

CONCERNS, GAPS, AND SPECULATIONS

Primary among our concern's is the effect of siltation, which occurs during silt-generating activities (e.g., dredging), in the vicinity of significant razor clam beaches. A discussion of the serious impacts of siltation, especially during and after the time of setting, was given by Nickerson (1975).

The effects of low sub-surface oxygen is another concern. McMillan (1924) felt that razor clams require relatively high levels of dissolved oxygen, although data on the subject are lacking. In an era of increasing nearshore oil exploration, in the event of an oil spill, sub-surface oxygen may be affected. We are not prepared to say how that would impact razor clams.

Another gap in our understanding of razor clam biology is the real extent and importance of subtidal populations. Understandably, rough surf has prevented such data from being routinely gathered. At a minimum, however, it seems that the concept of these subtidal populations acting as brood stock for intertidal populations should be verified. Early and recent authors seem to differ on the topic of larval drift. Is there a large pool of far-ranging larvae in offshore waters, or is larval drift limited and must local stocks produce recruits for their own replacement?

Finally, a speculation: relatively fast growth; the recent successes of enhancement efforts in spawning, rearing, and transplanting razor clams; and a high, stable market price suggest to us (as it did to Schink et al. 1983) that razor clam aquacultural operations remain a distinct future possibility.

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50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO. Biological Report 82(11.89)*

2.

3. Recipient's Accession No.

4. Title and Subtitle

Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest)--Pacific razor clam

5. Report Date

January 1989

6.

7. Author(s)

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10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

National Wetlands Research Center
U.S. Department of Interior
Fish and Wildlife Service
Washington, DC 20240

U.S. Army Corps of Engineers
Waterways Experiment Station
P.O. Box 631
Vicksburg, MS 39180

13. Type of Report & Period Covered

14.

15. Supplementary Notes

*U.S. Army Corps of Engineers TR EL-82-4

16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, distribution, life history, ecological role, fishery (when appropriate), and environmental requirements of coastal aquatic species. They are prepared to assist coastal managers, engineers, and biologists in the gathering of information pertinent to coastal development activities. The Pacific razor clam has a long history of human consumption on the west coast. Turn-of-the-century commercial canning operations have given way to today's extensive recreational fishery. Razor clams spawn in late spring and early summer in the Pacific Northwest and recruit to flat, sandy beaches in late summer. Greatest densities of large clams occur in the lower intertidal zone. Razor clams grow and mature faster but attain a lower maximum size and age in the southern part of their range. They are noted for their unusual ability to dig very rapidly through the subsurface sand. Silt-generating activities should be avoided in the vicinity of razor clam beaches, as juveniles are susceptible to suffocation.

17. Document Analysis a. Descriptors

Exposed beaches	Movement	Recreational diggers	Siltation
Intertidal zone	Growth	Wastage	Clams
Set/recruitment	Feeding habits	Temperature	Aquaculture
Fisheries	Predators	Sediments	

b. Identifiers/Open-Ended Terms

Pacific razor clam
Siliqua patula
Life history
Environmental requirements

c. COSATI Field/Group

18. Availability Statement

Unlimited

19. Security Class (This Report) Unclassified

20. Security Class (This Page) Unclassified

21. No. of Pages 16

22. Price

(See ANSI-Z39.16)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
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